Signal Processing: *Image Communication* 29 (2014) 167–176

Contents lists available at ScienceDirect

Signal Processing: *Image Communication*

journal homepage: www.elsevier.com/locate/image

Reduced-reference stereoscopic image quality assessment based on view and disparity zero-watermarks

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ARTICLE INFO

Article history:
Received 22 May 2012
Received in revised form
21 October 2013
Accepted 23 October 2013
Available online 6 November 2013

Keywords:
Three dimensional TV
Stereoscopic image processing
Image quality
Reduced-reference
Zero-watermark

ABSTRACT

As a practical and novel application of watermarking, this paper presents a zero-watermarking based objective reduced-reference stereoscopic image quality assessment (RR-SIQA) method. In the proposed method, two kinds of zero-watermarks are constructed according to the characteristics of image structure and stereoscopic perception. Concretely, two view zero-watermarks, which are constructed by judging the relation of the horizontal and vertical components of gradient vectors with respect to the two views, are used to reflect the image structure variation of the stereoscopic image. Meanwhile, a disparity zero-watermark, which is constructed with disparity map of the stereoscopic image, is used to reflect the stereoscopic perception quality variation. Then, the quality of stereoscopic image is objectively assessed by pooling the recovering rates of the detected zero-watermarks. The experimental results show that the stereoscopic image quality evaluation results assessed with the proposed RR-SIQA method are well consistent with subjective assessment, and the proposed method achieves better performance than the widely used full-reference stereoscopic image quality assessment method PSNR in assessing quality of stereoscopic images compressed with JPEG and JPEG2000.

1. Introduction

With the technological advancement made in computer graphics, computer vision and network communication [1,2], stereoscopic image processing is becoming increasingly popular and would possibly have many applications [3]. In these applications, stereoscopic images may have gone through various processes, including compression, communication, printing, display, restoration, segmentation, and fusion [4], any of which can introduce distortions that may impair visual qualities of the images. On the other hand, with the evolution towards new multimedia communication systems and services, users now expect services to be delivered according to their demands on quality [5]. Recently, the concept of quality of service (QoS) has been extended to the new concept of quality of experience (QoE), combining user perception, experience, and expectations with non-technical and technical parameters such as application- and network-level QoS [6]. However, for wireless systems the possible limitations due to the features of the devices and of the transmission channel may result in perceivable impairments that influence the user's perception on images. Therefore, stereoscopic image quality assessment (SIQA) is necessary since it enables to adjust the parameters of stereoscopic image processing so as to optimize stereoscopic image quality or make it to reach a given quality [7].

SIQA methods can be classified as subjective and objective methods. Subjective SIQA method is closer to

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http://dx.doi.org/10.1016/j.image.2013.10.005

human visual perception [8]. However, it is time consuming and expensive, and cannot be done in real time. By contrast, the objective SIQA method needs less time and is convenient to be implemented. Simple fidelity methods such as mean square error (MSE) or peak signal-to-noise ratio (PSNR) are often used to evaluate the quality of a processed stereoscopic image in the light of the original ones [9–11]. These methods belong to the so-called full-reference stereoscopic image quality assessment (FR-SIQA) methods, which require full information of the original stereoscopic image [12–15]. However, since the end-user usually cannot obtain the original image through the wired or wireless network, it is difficult to implement full-reference image quality assessment in real applications. The opposite is the No Reference (NR) model which does not need any information about the original image, but these kind of methods are useful only when the types of distortions that the stereoscopic images suffered by are fixed and known [16,17]. Thus, they may be limited in modern wired or wireless network, where the distortions could be a combination of lossy compression, network delay and packet loss, and various types of pre and post-processing filtering. On the other hand, general-purpose NR model is still at its immature stage.

Reduced Reference (RR) model is another alternative method, the concept of which is basically proposed in [18]. In this manner, an image is transmitted to the receiver side via a transmission channel, which may introduce distortions to the received image. Meanwhile, RR features extracted from the original image at the transmitter side, which usually have much lower data rate than the image data, are sent to the receiver side through an ancillary channel, and RR features extracted from the distorted image at the receiver side are then compared with the RR features of the original image to yield a quality score for the distorted image. Benefitting from some known features of the original images, RR models usually can achieve more accurate assessment than the NR models. On the other hand, RR image quality assessment (IQA) methods require only a reduced amount of information from the original images. This makes them more useful in multimedia communications over wired or wireless networks compared with Full Reference (FR) models, where the full information of the original images is often not available. For example, Atzori et al. proposed a source rate control scheme for streaming video sequences over wireless channels by resorting on a reduced-reference quality estimation approach [19]. Over the years, some scholars contributed significant research in the design of RR mono-scopic image quality assessment methods [20–27]. The researches on RR mono-scopic video quality assessment have also been made some progress. Soundararajan et al. presented a family of reduced reference video quality assessment models that utilize spatial and temporal entropic differences for video quality assessment [28]. A Gaussian scale mixture model for the wavelet coefficients of frames and frame differences is used to measure the amount of spatial and temporal information differences between the reference and distorted videos, respectively. Recently, the reduced-reference stereoscopic image quality assessment (RR-SIQA) also has been made some progresses [29–31]. Maalorf et al. proposed a RR-SIQA for color stereoscopic images by studying the relation between the disparity maps of the original and the distorted stereoscopic images and comparing the sensitivity coefficients of the stereoscopic images [29]. Hewage et al. proposed a RR-SIQA for color plus depth based 3D video transmission [30,31]. As a well known information hiding technologies, watermarking are proposed for applications such as copyright protection, certification in the past dozen years [32–35]. But nowadays, fragile watermarks are also adopted to measure distortion degree of an image, thus some watermarking based mono-scopic IQA methods have become an active research topic [36–38]. Wang et al. proposed a digital watermarking based mono-scopic IQA method in which a watermark is embedded into the discrete wavelet transform (DWT) domain of the original image using a quantization method [36]. Similarly, watermarking based method is also used to assess the quality of video [37]. Bhattacharya et al. proposed a novel approach which makes use of both fragile and robust watermarking techniques. The embedded fragile watermark is used to assess the degradation undergone by the transmitted images, while robust image features are used to construct the reference watermark from the received image, for assessing the amount of degradation of the fragile watermark [38]. However, since a watermark signal is inserted into the host image, visual quality degradation is introduced. By contrast, zero-watermark techniques extract some characteristics from the host image and use them for watermark detection, instead of watermark embedding. Thus, the distortion to the host image due to watermark embedding is eliminated [39].

In this paper, a new RR-SIQA method using view and disparity zero-watermarks is proposed. Since stereoscopic image degradation deforms image structure and descends quality of stereoscopic perception, zero-watermarks are constructed according to characteristics of image structure and stereoscopic perception, so that the recovering rates of the detected zero-watermarks can be used to evaluate the quality of stereoscopic image.

2. The proposed RR-SIQA method

In this paper, we evaluate quality of stereoscopic image from the viewpoint of image quality and stereoscopic perception quality. Fig. 1. shows diagram of the proposed SIQA method. View zero-watermark is constructed by judging the relation of horizontal and vertical components of gradient vectors, because the variation of gradient can reflect the change in image structure. Disparity zero-watermark, which is constructed with disparities between the left and right views of stereoscopic image, is used to describe the stereoscopic perception quality of stereoscopic image. Then, RR-SIQA score is obtained by pooling the zero-watermark recovering rates of the view zero-watermarks and the disparity zero-watermark to assess the quality of stereoscopic image.

2.1. Construction and detection of view zero-watermark

Image degradation deforms the image structure, thus analysis of structural distortions of image is beneficial to IQA. Gradient vector, as a good representation of visual quality variations in sharpness, can be used for gauging structural changes in the left and right views of stereoscopic image.